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U. S. NAVAL AIR DEVELOPMENT CENTER

JOHNSVILLE, PENNSYLVANIA

Aviation Medical Acceleration Laboratory

NADC-MA-6303 8 April 1963

Lever Displacement During a Discrimination-Differentiation

Bureau of Medicine and Surgery
Subtask MR005.13-0002.16 Report No. 10

Bureau of Naval Weapons
Weptask R360 FR102/2021/R01 10 1001 (50-3-02)

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SUMMARY

The maximum displacement of the T-bar handle of a rat response lever was recorded under two schedules: (a) programed variable-duration S^D and S^Δ periods with reinforcement only for S^D presses between 23.54° and 28.64° (Position 5) and (b) the same requirements for a reinforcement as in (a) but with S^Δ initiated only by a "wrong" press in S^D, and prolonged by any press in S^Δ. With this lever, work is linearly proportional to displacement. Under the first schedule (a) S^D distributions differed significantly from their companion S^Δ distributions, although the lever position showing the greatest percentage of presses in S^D often corresponded with the one showing the greatest percentage in S^Δ and (b) both mean lever displacement and variability were consistently greater in S^Δ than in S^D. Under the second schedule (a) S^D distributions differed significantly from their companion S^Δ distributions, but the S^D - S^Δ distributions were positively correlated and (b) mean lever displacement was about the same in S^D and S^Δ, but variability was consistently greater in S^Δ. Under both schedules (a) the previously-established discrimination was disrupted initially, but eventually reached very high levels, (b) the final shape of the S^D distribution was asymmetrical with respect to Position 5; more presses occurred below than above Position 5, (c) the greater the distance from Position 5, the lower the final percentage achieved, (d) while the mean response rate in S^D decreased under lowered motivation, the distance the lever was pressed remained unchanged.

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INTRODUCTION

To evaluate the influence of zero g or above-normal g on the motor behavior of animals one must first develop standards of normal motor behavior. To help provide such standards an earlier report (3) presented data on a lever displacement measure. The work expended in pressing this lever is linearly proportional to the lever displacement. The maximum distance a lever handle was pressed was measured under two schedules (a) continuous reinforcement for all presses and (b) alternating variable-duration periods of continuous reinforcement for all presses (S^D) and extinction (S^Δ), with a cue light associated with the alternations. The present report describes lever displacement measures in two additional experiments (a) a discrimination-differentiation and (b) a discrimination-differentiation with S^Δ initiated by a "wrong" press in S^D and prolonged by any press in S^Δ.

METHOD

Subjects

Six male albino rats of Sprague-Dawley strain served as Ss. Their earlier operant conditioning experience is described elsewhere (3). All were about 75 days old at the start of Phase III.

Apparatus

In the earlier report are given descriptions of the Skinner Box, the water reinforcement device (.02 cc cup), the cue lights, the response lever, the recording system, and the physics of a press. In short, the arc through which the T-bar handle of the lever moved as a result of a press was categorized into class intervals or lever positions. The "Home" Position represented 3.14° of arc. Each of the next seven lever positions (Positions 1 through 7) represented an additional 5.10° (4.52 mm) of arc, and, because of an erroneous adjustment, Position 8 represented only 2.50° rather than 5.10°. A minimum force of 26,500 dynes (27 g) was required to move the T-bar, and this minimum force requirement remained constant throughout the total excursion of the T-bar. Angular displacement of the T-bar was related to work by the equation, Work = $134{,}620\ \theta$, with work in dyne-cm and θ in radians.

For each press, the maximum displacement of the T-bar was measured in lever position units. For example, if the T-bar was moved off the Home Position, through Positions 1, 2, 3, 4, stopped somewhere in the interval of arc called Position 5, and then returned to the Home

Position, a count was recorded for a press to Position 5. Such a count was cumulated along with other counts representing lever presses of the same displacement interval. In S^D, eight counters recorded this information for Positions 1 to 8, and in S^Δ, eight additional counters recorded similar information. A photograph of the counter display was taken every 20 minutes during a session.

Procedure

Preceding Phases III and IV, the rats were trained under the two schedules summarized in the introduction (and called Phases I and II in the earlier report). Phase III began two days after the completion of Phase II.

Phase III. Simultaneously, two cue lights alternated on (S^D) and off (S^Δ) for periods of 30, 60, 90, or 120 seconds. Each daily session consisted of 52 S^D periods totalling one hour, and 52 S^Δ periods totalling one hour. During S^D periods, only presses to Lever Position 5 were reinforced; i.e., for a reinforcement, the T-bar had to be pressed at least 23.54° [$3.14^\circ + 4\ (5.10^\circ)$] but not more than 28.64° [$3.14^\circ + 5\ (5.10^\circ)$], and then allowed to return to the Home Position. During S^Δ periods no presses were reinforced. This phase lasted 10 consecutive days.

Phase IV. In this phase the S^D and S^Δ durations were not programed but were determined solely on the basis of the rat's lever-pressing behavior. When the cue lights were on (S^D), each press to Lever Position 5 was reinforced and the lights remained on. A press to any position other than Position 5 caused the lights to go off (S^Δ) and remain off for 10 seconds. A press to any position during S^Δ delayed the onset of S^D until 10 seconds after the completion of the press. Each daily session lasted two hours. This phase lasted 30 consecutive days.

In Phases III and IV the session for each rat was at the same time daily. Besides the water available as reinforcement, each rat had access to a water tube for 15 minutes immediately following its daily session. Purina Laboratory Chow was available to the rat at all times.

RESULTS AND DISCUSSION

In Phase III, hundreds of S^D and S^Δ lever displacement distributions were recorded; in Phase IV, over two thousand distributions were recorded. However, to conserve space, the presentation of data that follows has been restricted, almost exclusively, to the daily distributions. Also, the data are described in lever position units. The reader may convert these units to other units of angular displacement or to units of work. The conversion factors, derived from information in the apparatus section, are: 1^o of arc of the T-bar is equivalent to 0.8863 mm of arc or 2,349 dyne-cm of work or 2.397 g-cm of work. Thus, a press to the class interval called Position 5 means that the press was between 23.54 and 28.64^o or 20.86 and 25.38 mm and represented between 55,295 and 67,275 dyne-cm or 56.42 and 68.65 g-cm of work.

Phase III. In the S^D periods on the last day of Phase II, 5 of the 6 rats made 61.3 to 95.9% of their presses to Position 1 and only 0.0 to 0.6% of their presses to Position 5. Thus, at the start of Phase III, the behavior required for a reinforcement was occurring very infrequently.

Figure 1 gives samples of daily S^D and S^Δ distributions of Phase III. The Day 1 data indicate that the shift to the differentiation almost resulted in extinction of the response for Rats #5 and 6. Compared with the last day of Phase II, all rats showed at least some deterioration in the discrimination. All of the rats except Rat #3 gradually increased the daily percentage of presses to Position 5 in S^D. On Day 3, Rat #3 gave 47.4% of its S^D presses to Position 5. On subsequent days its percentage of presses to Position 5 in S^D was only 24.6 to 35.1% while its percentage of presses to Position 4 was 27.5 to 42.9%. The persistence of Position 4 presses may have resulted from reinforcement received for a sequence of presses that included one or more Position 4 presses. Unfortunately, the sequence of the presses was not recorded, so an evaluation of this hypothesis of adventitious chaining is not possible.

Statistical comparisons of distributions of Figure 1 were made by means of the Kolmogorov-Smirnov (K-S) two-sample, two-tail test, with the chi-square approximation (5, p 135) used when the number of presses in either of the two distributions compared was less than 40. Three sets of comparisons were made. Figure 1 describes these comparisons and presents the results for the individual rats. In 24 of the 30 S^D - S^Δ comparisons, an S^D distribution differed significantly

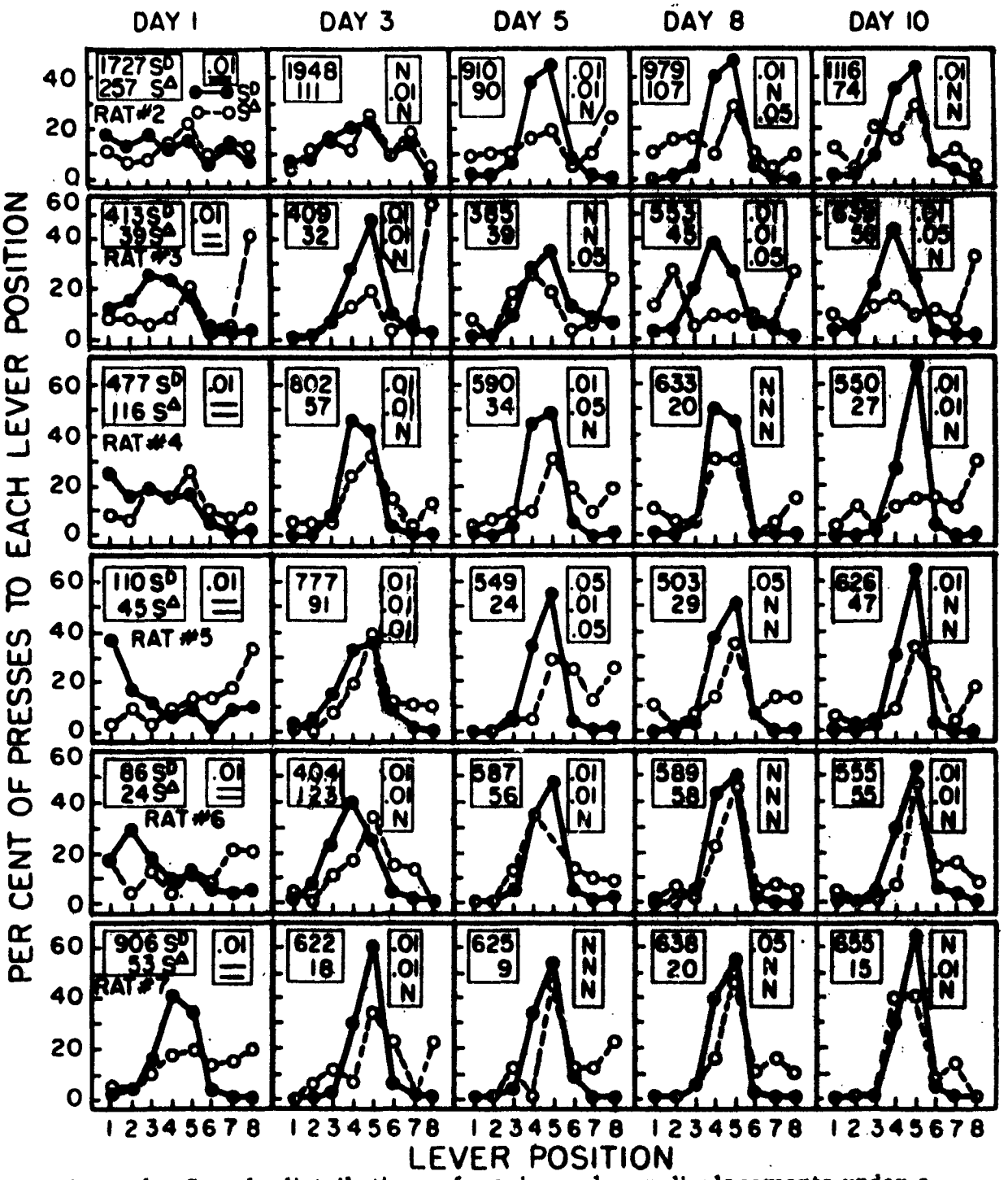

Figure 1. Sample distributions of maximum lever displacements under a discrimination - differentiation schedule. Reinforcement was given only for presses to Position 5 in S^D. Total S^D presses daily equals 100%; total S^Δ presses daily equals 100%. The number of S^D and S^Δ presses are shown in the left-hand box of each rectangle. Each right-hand box gives in descending order, the level of the significance of the difference between (a) an S^D distribution and its companion S^Δ distribution, (b) an S^D distribution and the preceding S^D distribution in this figure, (c) an S^Δ distribution and the preceding S^Δ distribution in this figure. N means no significant difference.

from its companion S^{Δ} distribution. In 15 of the 24 S^{D} - S^{D} comparisons, an S^{D} distribution of a rat differed significantly from the preceding S^{D} distribution of Figure 1. In only 5 of the 24 S^{Δ} - S^{Δ} comparisons did an S^{Δ} distribution differ significantly from the preceding S^{Δ} distribution.

One might expect that the S^{Δ} behavior is correlated with the S^{D} behavior. Calculation of the rank order coefficient of correlation for each S^{D} - S^{Δ} pair of distributions in Figure 1 indicated, however, that this was rarely the case. Of the 30 correlation coefficients, only 6 reached the .05 level of significance. Although few coeffecients showed a correlation, Figure 1 does indicate that the lever position showing the greatest percentage in S^{D} is often the one showing the greatest percentage in S^{Δ}. In light of the above, it seems reasonable to hypothesize that the S^{Δ} behavior reflects the S^{D} behavior but is distorted by the influence of the extinction process in S^{Δ}.

A comparison of the day-to-day changes in the percentage of presses to each lever position in S^{D} was made for each rat. Table 1 shows this evaluation for one rat, and Table 2 summarizes the findings for all six rats.

Figure 2 shows the development of the differentiation for the rats. In the creation of this figure, the percentage of daily S^{D} (or S^{Δ}) presses to a given position was determined for each rat, and the median of these six values was plotted. A semi-logarithmic plot was used to give equal emphasis to the Positions with small percentages. The data of Day 7 were lost in the photographic processing, so Day 7 data are not included in Figure 2 or in subsequent figures.

Figures 3 and 4 summarize the data of Phase III. With the lever position units, the largest mean lever displacement possible is 8.0 (occurring if all presses are made to Position 8) and the smallest is 1.0. The largest mean deviation possible is 3.50 (occurring if 50% of the presses are made to Position 1 and 50% to Position 8), and the smallest is 0.0 (occurring if all presses are made to the same Position). The mean lever displacement in S^{D} in Figure 4 is about 4.5 lever position units. This is equivalent to 23.54° or 20.86 mm or 55,295 dyne-cm or 56.42 g-cm. Similarly, the S^{Δ} mean of 5.0 is equivalent to 26.09° or 23.12 mm or 61,285 dyne-cm or 62.54 g-cm. Taking the S^{D} variability of Figure 4 as 0.65, the equivalent units are 3.32° or 2.94 mm or 7,799 dyne-cm or 7.96 g-cm. The S^{Δ} variability of 1.50 gives equivalent values of 7.65° or 6.78 mm or 17,970 dyne-cm or 18.34 g-cm.

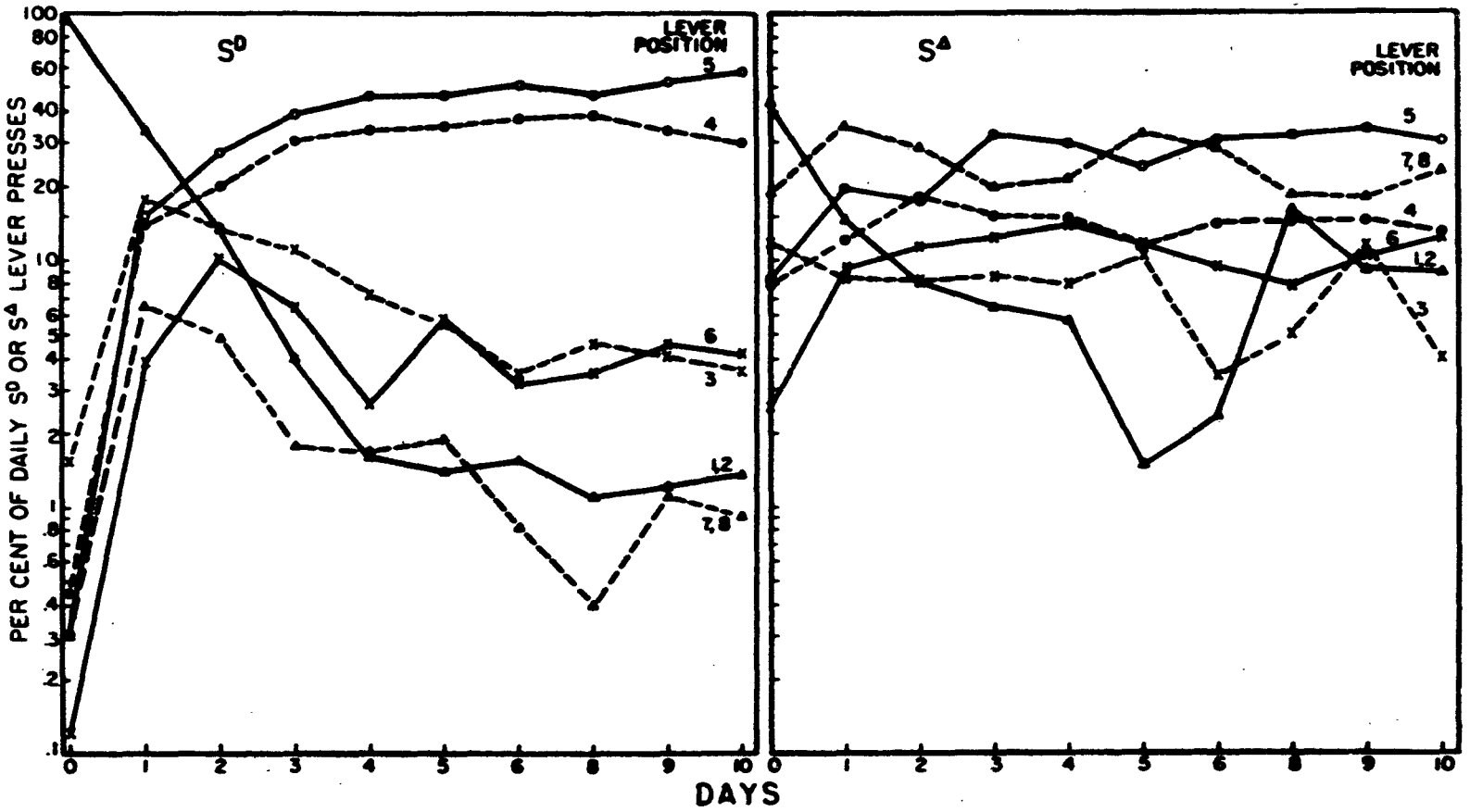

Figure 2. Development of a discrimination - differentiation. Reinforcements given only for presses to Position 5 in S^D. Day 0 is the last day (of Phase II) on which presses to all Lever Positions were reinforced. Each point is the median percentage value for six rats.

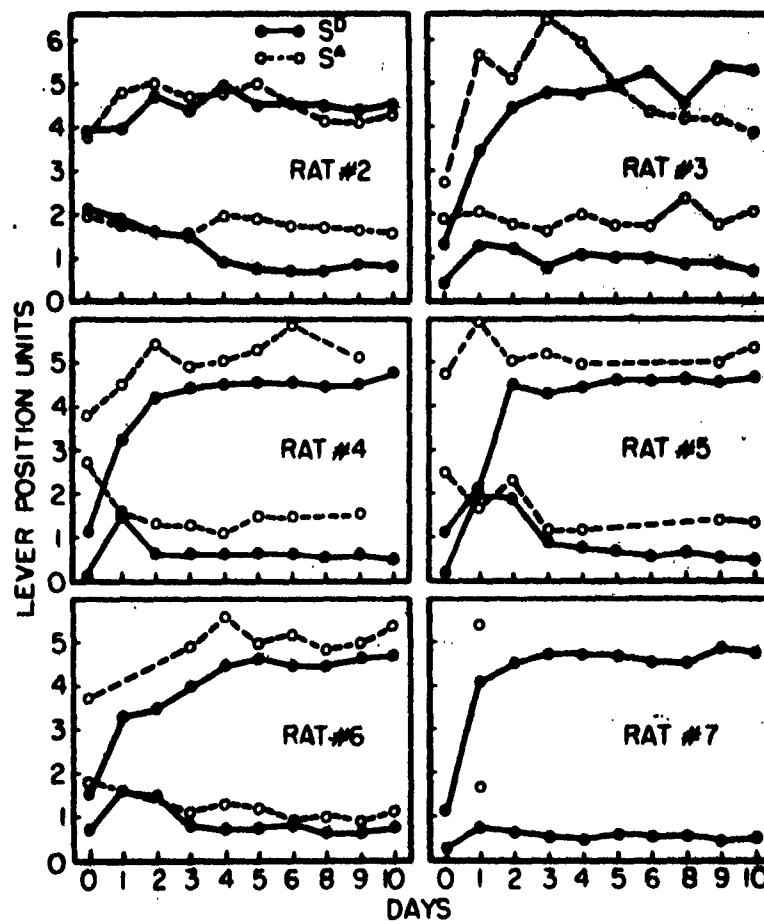

Figure 3. Mean lever displacement and variability during a discrimination - differentiation. In each box the upper pair of curves gives the mean lever displacement, and the lower pair gives the mean deviation of lever displacements. Day 0 is the last day on which presses to all Positions were reinforced. A point was omitted if it was based on 30 presses or less.

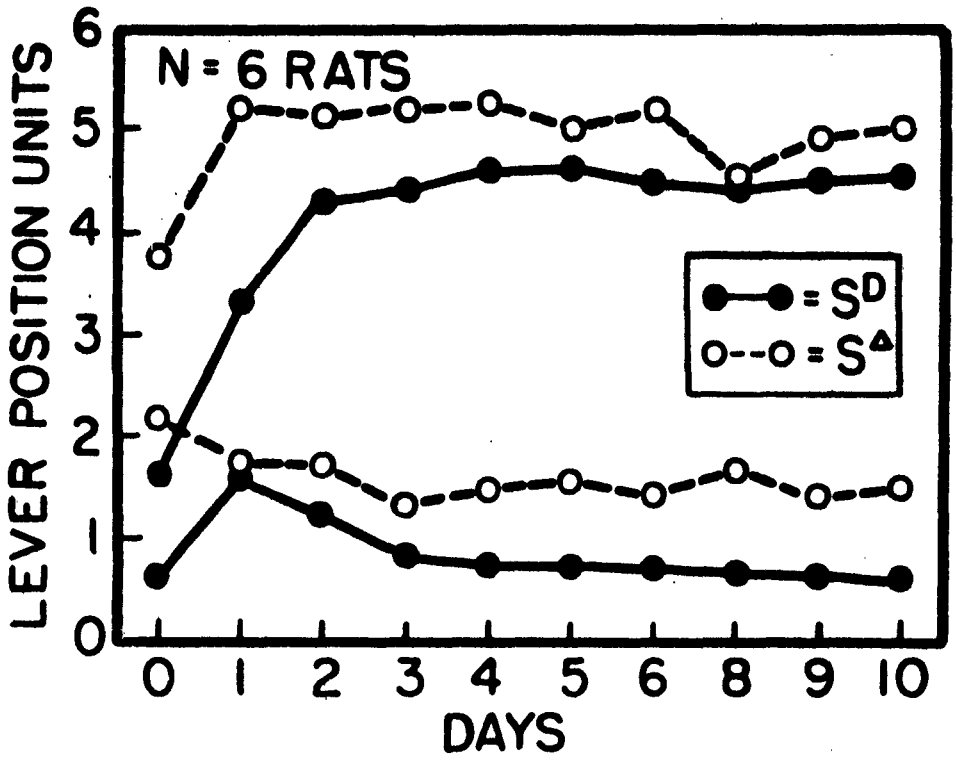

Figure 4. Mean lever displacement and variability during a discrimination-differentiation. Upper pair of curves gives mean lever displacement; lower pair gives mean deviation of lever displacements. Day 0 is the last day on which presses to all Positions were reinforced. Data points are the means of Figure 3 points.

By dividing the mean deviation by the mean, a measure of the relative variability is obtained. Applied to the data of Figure 4, this measure indicated that the relative variability was greater in S^{Δ} than in S^{D}.

Because of the large number of reinforcements received during the course of a daily session (see Figure 1), one might expect the differentiation to be affected somehow—to improve or to deteriorate as motivation decreased. Figure 5 indicates, however, that this is not the case: the percentage of presses to Position 5 remains fairly stable throughout the daily session; the few significant deviations that do occur provide no consistent pattern. For the rat in Figure 5 that shows the greatest number of deviations, other measures of the differentiation are given in Figure 6. Again, one sees the absence of a pattern within a daily session. This result is related to Elliott's findings (2). Using a 5-alley apparatus, he found that once variability in the selection of alleys had been reduced, it did not change when the animals were tested under low motivation.

Figure 7 provides indices of the development of the discrimination-differentiation during Phase III. Cumulative records of total S^{D} presses versus time (not shown) indicated considerable fluctuations in rate of pressing initially. Later, a steady rate interspersed with periods of no pressing developed. Similar S^{Δ} records showed fairly low fluctuating rates initially and still lower rates later, with a tendency for S^{Δ} presses to occur in groups.

In comparing the data of Phase III with that of the earlier phases, two points are worth noting. First, although Rat #2 behaved atypically in Phase II, its behavior in Phase III was similar to that of the other rats.

Second, although a great number of reinforcements was received for presses to certain Positions in Phases I and II, often few presses were emitted to these Positions when the differentiation procedure was introduced. Rat #7, the extreme example, received over 6000 reinforcements for presses to Position 1 in Phases I and II. Yet, on the first day of Phase III, only 23 of its 906 S^{D} presses were given to Position 1; on the next two days, no presses to Position 1 occurred; on the fourth day, one press was made to Position 1. The same rat received almost 4000 reinforcements for presses to Position 2 in Phases I and II but made only 39, 7, 3, and 0 S^{D} presses, respectively, to Position 2 on the first four days of Phase III. Thus, valid predictions of the frequency of occurrence of a particular response class (e.g., press

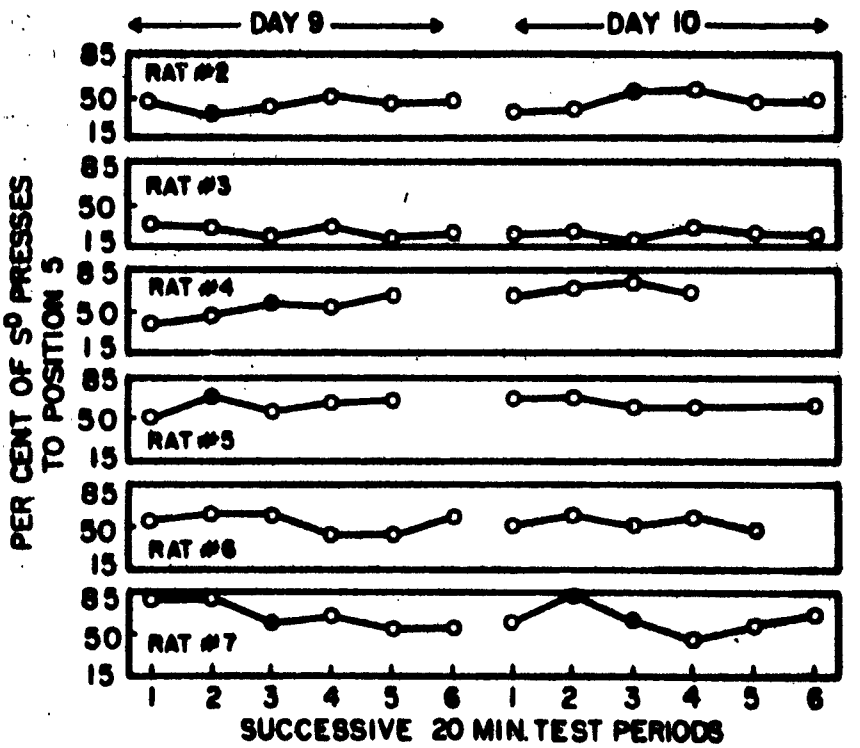

Figure 5. Variability in the percentage of S^D presses to Position 5 during the last two days of Phase III. Each point represents about 10 minutes of S^D data. A percentage represented by a filled-in point differed significantly (.05 level, "two-tail" test; Wallis & Roberts, 1956, p 429) from the preceding percentage. Missing points mean no presses.

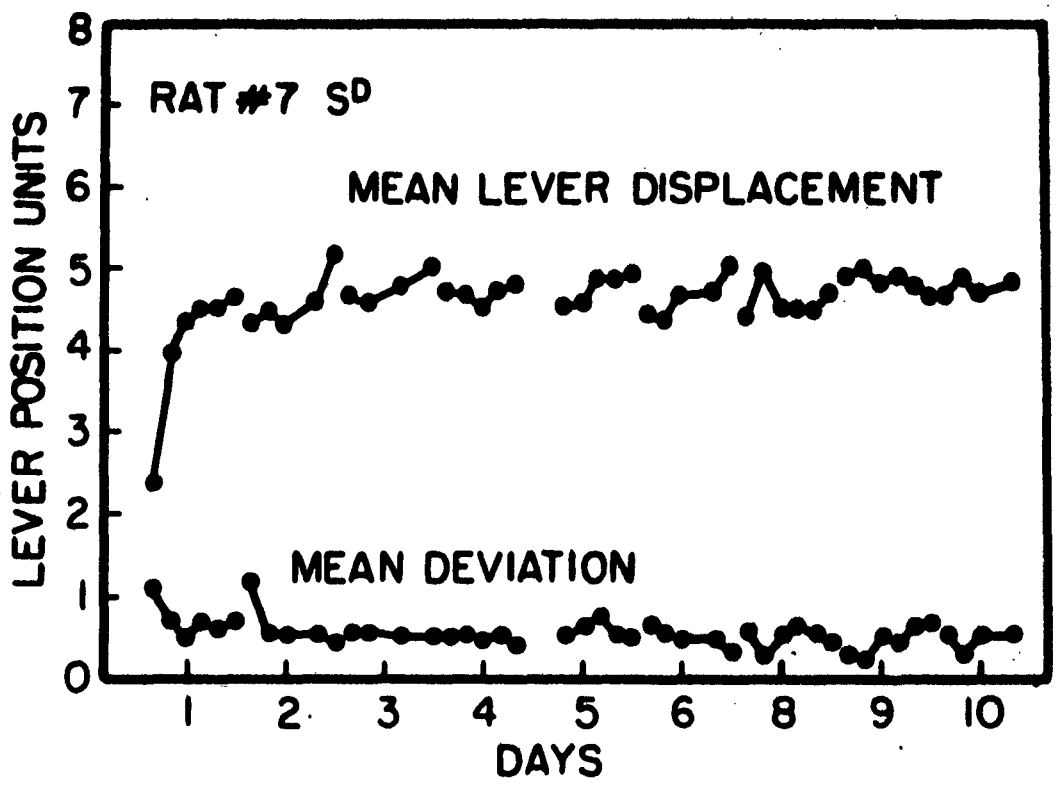

Figure 6. Central tendency and variability measures in S^D during successive 20-min. test periods (i.e. about 10 min. of S^D) of daily sessions. Point omitted if it was based on less than 50 presses.

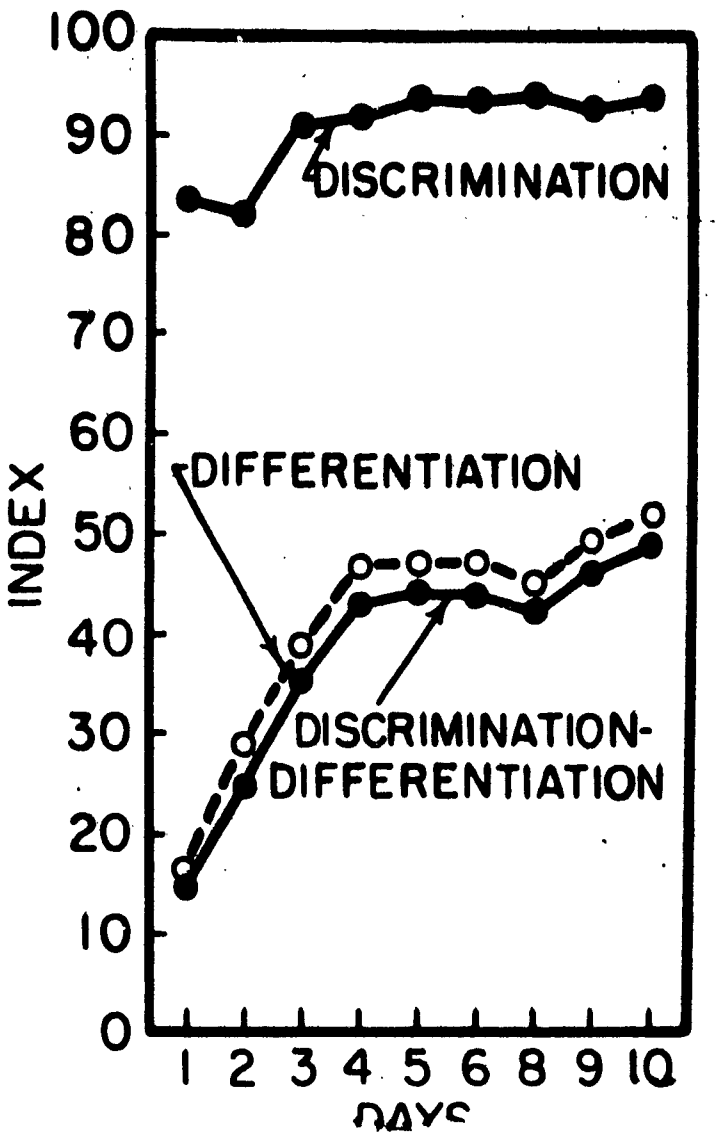

Figure 7. Three indices of a discrimination - differentiation. The discrimination index gives, of the total number of presses, the percentage made in S^D. The differentiation index gives the percentage of S^D presses made to Position 5. The discrimination - differentiation index gives, of the total number of presses, the percentage made to Position 5 in S^D. Mean data of six rats, each rat contributing equally to each experimental point.

to Position 1) under changed reinforcement conditions cannot be based, in any simple fashion, on the number of reinforcements already received for the emission of that response. As Skinner noted with respect to the beginning of a differentiation of high force, "the relative frequency of strong responses immediately increases". (6, p. 314, italics added).

The last column of S^D curves in Figure 1 indicates that most of the S^D presses that fall outside the reinforcement zone, i.e., outside the limits of Position 5, fall below Position 5. The data of the differentiation studies of Arnold (1) and of Notterman and Mintz (4) give an analogous picture with respect to force: of the non-reinforced presses, more fell below the minimum force required for a reinforcement than fell above the maximum force acceptable for a reinforcement.

Phase IV. Introduction of the Phase IV schedule adversely affected both the discrimination and the differentiation of all rats except Rat #7. The lever pressing behavior of Rat #3, which was atypical in Phase III, was similar to that of the other rats in Phase IV. This improvement may have resulted from the Phase IV procedure which precluded reinforcement for a series of closely-spaced presses that included any press to a position other than Position 5. The percentage of presses to Position 5 in S^D did not begin to rise for about 3 to 5 days for Rats #5 and 6, and for about 10 to 15 days for Rats #2, 3, and 4.

Figure 8 provides sample distributions of Phase IV. As in Phase III, the K-S test was used to evaluate differences between distributions. Distributions based on less than 10 presses were excluded from these evaluations. For each rat the results of these comparisons are given in Figure 8. Significant differences were found in 17 of the 28 S^D - S^Δ comparisons, in 17 of the 30 S^D - S^D comparisons, and in 5 of the 20 S^Δ - S^Δ comparisons.

Because of the low number of presses in many of the daily distributions of Figure 8, particularly in the S^Δ distributions, many comparisons were omitted. Also, many of the comparisons probably indicated a non-significant difference because the difference found fell short of the very large difference required with a small number of presses. To a great extent, these objections are overcome when the data of several days are combined, as in Figure 9.

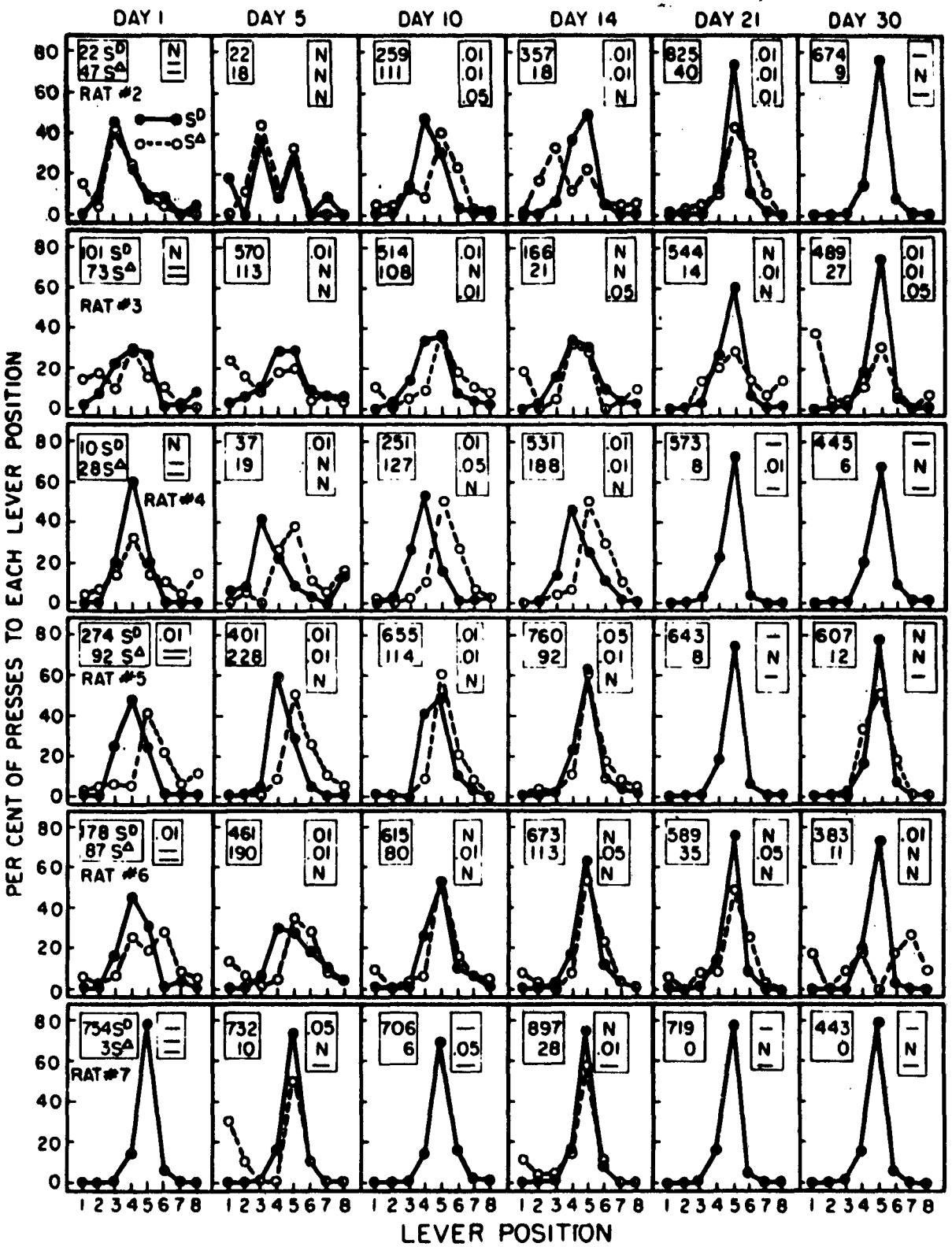

Figure 8. Sample distributions of maximum lever displacements in S^D and S^Δ in Phase IV. See Figure 1 caption for additional information on statistical tests. Data of Rat #4, Day 1 and of Rat #3, Day 14 are for only one hour. Rat #2 was not tested on Day 14; data shown are for Day 15

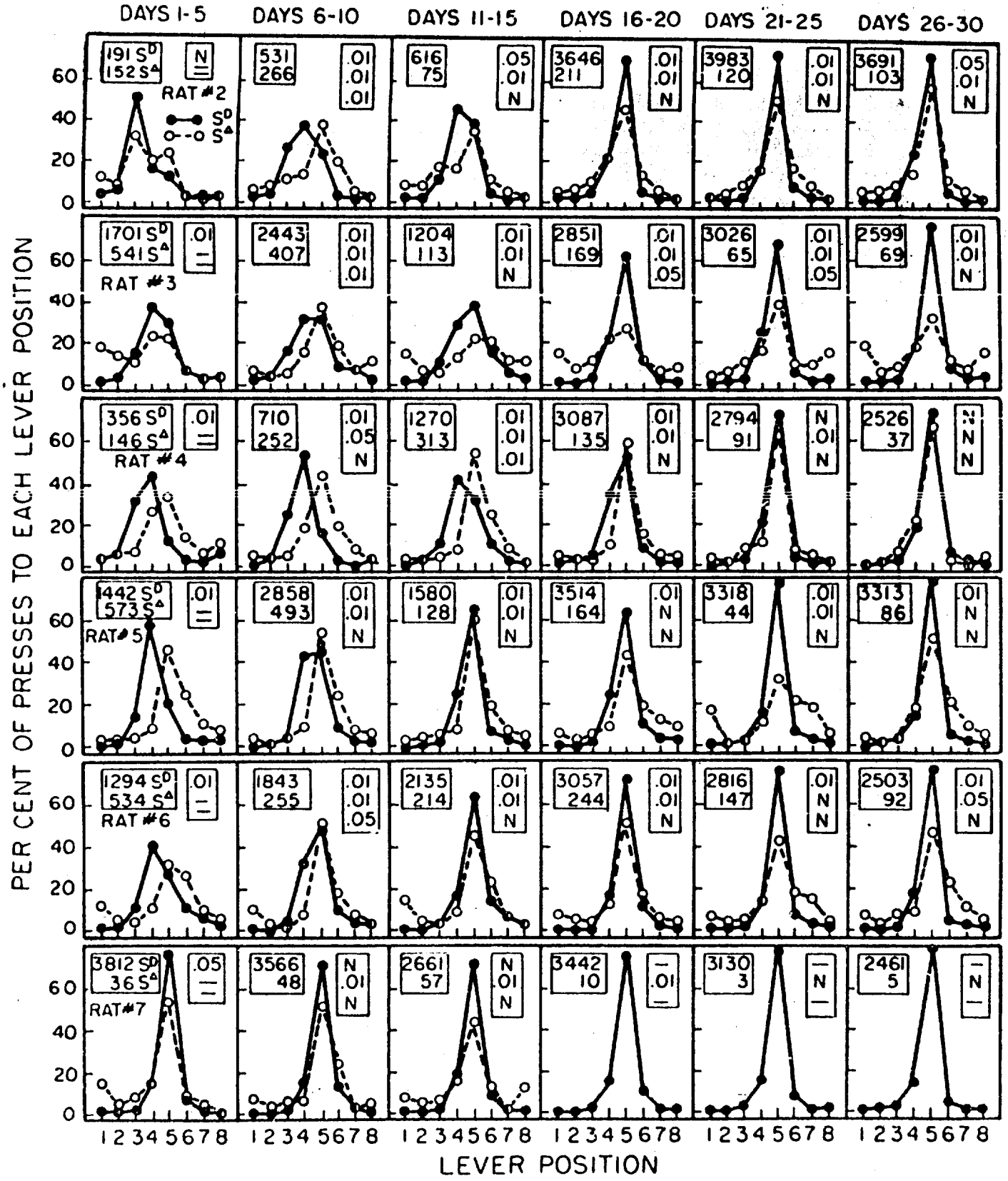

Figure 9. Distributions of maximum lever displacements of 5-day periods in Phase IV. See Figure 1 caption for additional information on statistical tests. During the Day 11-15 period each rat was tested on only 3 of the 5 days.

The Figure 9 distributions were subjected to the K-S test. Again, distributions of less than 10 presses were excluded from the comparisons. Significant differences were found in 28 of the 33 S^D - S^Δ comparisons, in 24 of the 30 S^D - S^D comparisons, and in 6 of the 27 S^Δ - S^Δ comparisons.

A second type of analysis of the Figure 9 data evaluated the changes in the percentage of presses to each lever position in S^D. First, tables similar to Table 1 were created. From them, Table 3 was compiled.

A third type of analysis examined the possibility of a correlation between the S^D distributions of Figure 9 and their companion S^Δ distributions. In some cases, inspection of Figure 9 indicated that the S^Δ distribution was similar in shape to the S^D distribution, but shifted to the right. In such cases, the S^D curve was shifted to the right, thereby dropping the Position 1 data in S^Δ and the Position 8 data in S^D, before the coefficient was calculated. Table 4 presents the results.

Comparison of the six S^D distributions for the last period of Figure 9 indicated a high degree of agreement among the rats: for the six rats, the percentage of presses to Position 1 all fell between 0.15 to 0.65%; to Position 2, between 0.08 to 0.63%; Position 3, 0.76 to 1.50%; Position 4, 12.76 to 18.84%; Position 5, 72.28 to 81.18%; Position 6, 3.47 to 5.18%; Position 7, 0.04 to 1.32%; Position 8, 0.00 to 0.88%. These percentage values may be considered a description of an equilibrium state achieved as a result of a large number of positive reinforcements for presses to Position 5 and a large number of mild negative reinforcements, viz., 10 sec. of S^Δ, for presses to other Positions.

For two rats, the S^D and S^Δ behavior is compared in Figure 10 in a semilogarithmic plot. For all six rats, central tendency and variability measures are provided by Figures 11 and 12. Since the S^D and S^Δ means in Figure 12 are about the same, and the absolute variability is greater in S^Δ, the relative variability in S^Δ is also greater.

Comparisons of the mean lever displacement in S^D and in S^Δ under the three discrimination procedures, i.e., under Phase II (3) Phase III, and Phase IV, indicate that the S^D and S^Δ means are functionally related: instead of obtaining any values between 1 and 8 for the mean lever displacements in S^Δ, the value obtained is always slightly higher, or the same as, its associated mean lever displacement in S^D. Even after exposure to a very great

TABLE I

Significant Day-to-Day Increases (+) and Decreases (-) in the Percentage of S^D Presses to Each Lever Position. Rat #4.

Days Compared	Lever Position							
	1	2	3	4	5	6	7	8
0[a] & 1	-	+	+	+	+	+	+	+
1 & 2	-	-	-	+	+		-	-
2 & 3		-	-		+			
3 & 4					+			
4 & 5						+		
5 & 6						-		
6[b] & 8						-		
8 & 9						+		
9 & 10					+			

Note.–Each comparison gives the significance of the difference between two percentages (Wallis & Roberts, 1956, p 429) with a "two-tail" test. + means that the percentage of presses to a given Lever Position on one day was higher than the percentage on the preceding day, at or beyond the .05 level of significance. An analogous meaning applies to the - symbol for decreases. No entry means that the change was not statistically significant.

[a]Day 0 is the last day of the phase in which presses to all Lever Positions were reinforced in S^D.
[b]Data of Day 7 were not recorded.

TABLE 2

Number of Rats Giving Significant Increases (+) and Decreases (-) in the Daily Percentage of S^D Presses to Each Lever Position (N=6 Rats)

Days Compared	Lever Position															
	1		2		3		4		5		6		7		8	
	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-
0[a] & 1		6	3		6		6		6		3		2		4	
1 & 2		4		4		4			4		3					
2 & 3		3		2		2	4		4							2
3 & 4				3		4			4			2				
4 & 5						2					3					
5 & 6					2							3		2		
6[b] & 8												2				
8 & 9								3	3		3					
9 & 10													2			

Note.—Entries in the + columns give the number of rats showing a percentage increase over the preceding day that is significant at or beyond the .05 level with a "two-tail" test. Entries in the - columns have a similar meaning with respect to a decrease.

For ease of reading, table entries of 0 and of 1 were omitted.

[a]Day 0 is the last day of the phase in which presses to all Lever Positions were reinforced in S^D.

[b]Data of Day 7 were not recorded.

TABLE 3

Number of Rats Giving Significant Increases (+) and Decreases (-) in the Percentage of S^D Presses to Each Lever Position (N = 6 Rats)

Periods Compared	Lever Position															
	1		2		3		4		5		6		7		8	
	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-
Days 1-5 vs. 6-10						4	2	3	3	1	3			1		2
6-10 vs. 11-15		1		2		5	2	4	5		3	1	1			1
11-15 vs. 16-20						3		4	5	1	1	3		3		2
16-20 vs. 21-25						2	1	3	6		1	5		1		
21-25 vs. 26-30							2	1	2			3				

Note.—Entries in the + columns give the number of rats showing a percentage increase over the preceding period that is significant at or beyond the .05 level with a "two-tail" test. Entries in the - column have a similar meaning with respect to a decrease.

TABLE 4

Rank-order Coefficients of Correlation Between S^D and S^Δ Distributions of Five-Day Periods

Period	Rat Number					
	2	3	4	5	6	7
Days 1-5	.91	.57	$.75^S$	$.88^S$	$.96^S$	.79
Days 6-10	$.93^S$	$.96^S$	$.89^S$	$.93^S$	.52	.57
Days 11-15	$.57^S$	.45	$.86^S$	.92	.57	.60
Days 16-20	.93	.60	.79	.80	.69	-
Days 21-25	.95	.85	.78	.68	.82	-
Days 26-30	.92	.55	.88	.64	.86	-

Note. — Coefficient of .64 required for significance at .05 level. For coefficients marked S (a) the S^D distribution was shifted one class interval (see text) and (b), a coefficient of .71 is required for significance at the .05 level.

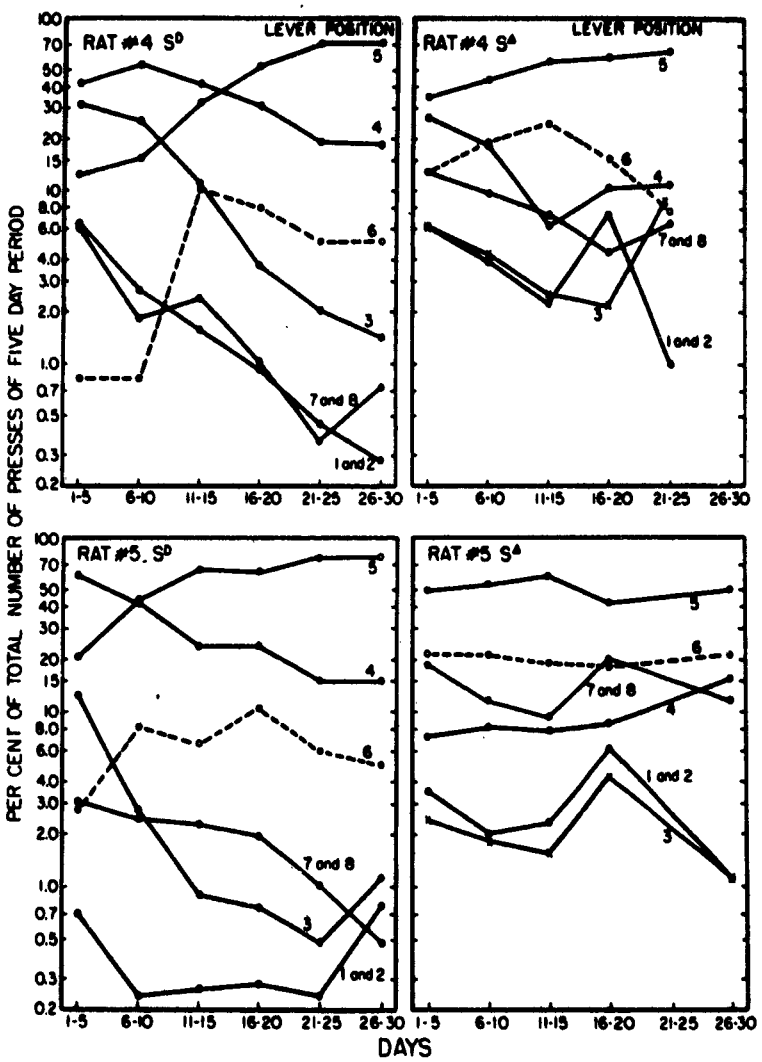

Figure 10. Redevelopment of the differentiation under Phase IV schedule. The total number of S^D presses during each 5-day period equals 100% as does the total number of S^Δ presses. Day 11-15 period represents only 3 days of data. Point omitted if the 5-day distribution included less than 50 presses.

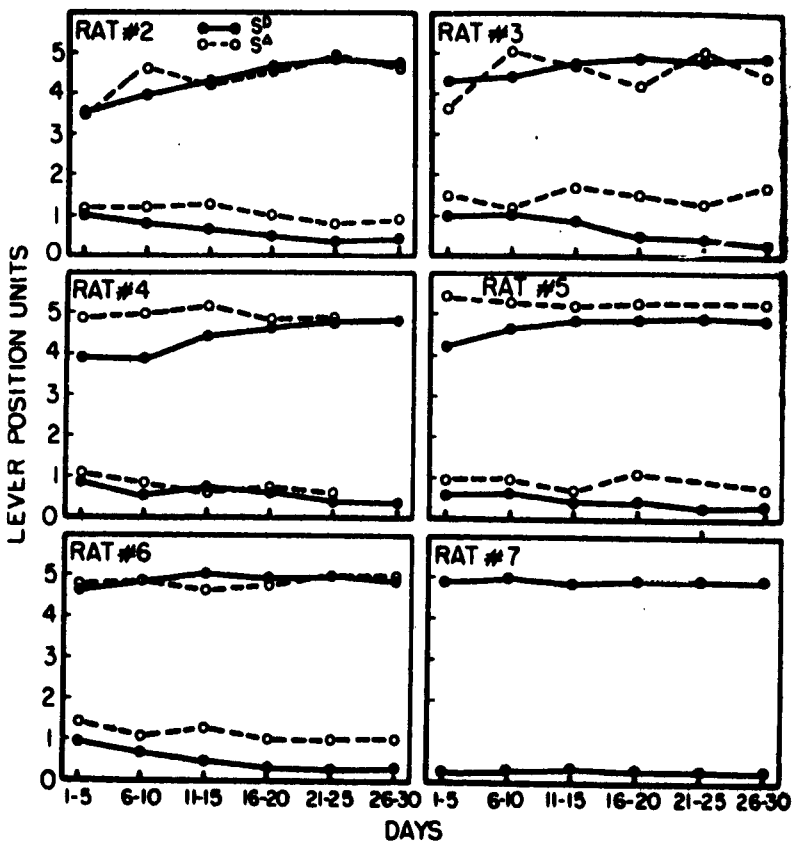

Figure 11. Mean lever displacement and variability under the discrimination - differentiation schedule of Phase IV. For each rat, the upper pair of curves gives the mean lever displacement, and the lower pair gives the mean deviation of lever displacements. Each point was derived from the total number of S^D (or S^Δ) presses during a 5-day period. Point omitted if the total number was less than 50. Day 11-15 period represents only 3 days of data.

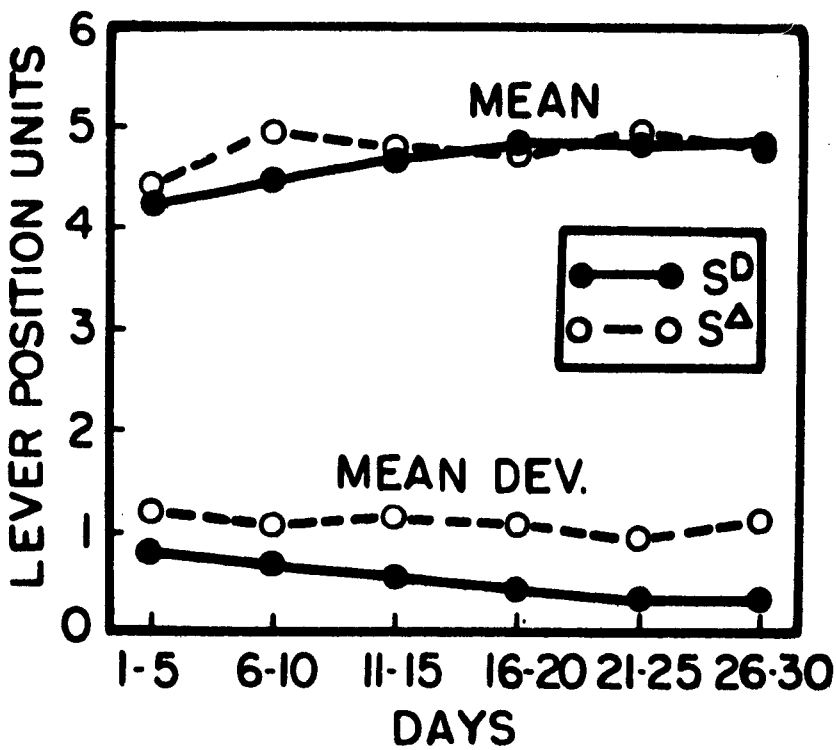

Figure 12. Mean lever displacement and mean deviation of lever displacements in Phase IV. Data points are the means of Figure 11 points.

number of S^{Δ} periods, during which the rate of responding in S^{Δ} drops to a very low value, this relationship between the S^{D} and S^{Δ} means remains.

Figure 13 indicates, as did Figure 5, that decreased motivation within a daily session did not influence the differentiation: a rat may not press under lower motivation, but if it does press, the displacement of the lever will be as it was under higher motivation.

Figure 14 provides indices of the discrimination and the differentiation. Fairly accurate estimates of the total duration of S^{D} and of S^{Δ} in a daily session may be derived by referring to the Procedure Section and to the Figure 8 distributions. As an example, on Day 1 Rat #7 gave about 168 presses in S^{D} to Positions other than Position 5 and a total of 3 presses in S^{Δ}. Thus, 1680 seconds of S^{Δ} resulted from "wrong" presses in S^{D}, and an additional 0 to 30 seconds of S^{Δ}, say 15 seconds, resulted from presses in S^{Δ}. The total S^{Δ} time was, therefore, 28.2 minutes; the total S^{D} time, 91.8 minutes.

Cumulative records of lever-pressing in S^{D} during the latter part of Phase IV are similar to the records during the latter part of Phase III except that the periods in which no presses are made are longer, typically, in Phase IV.

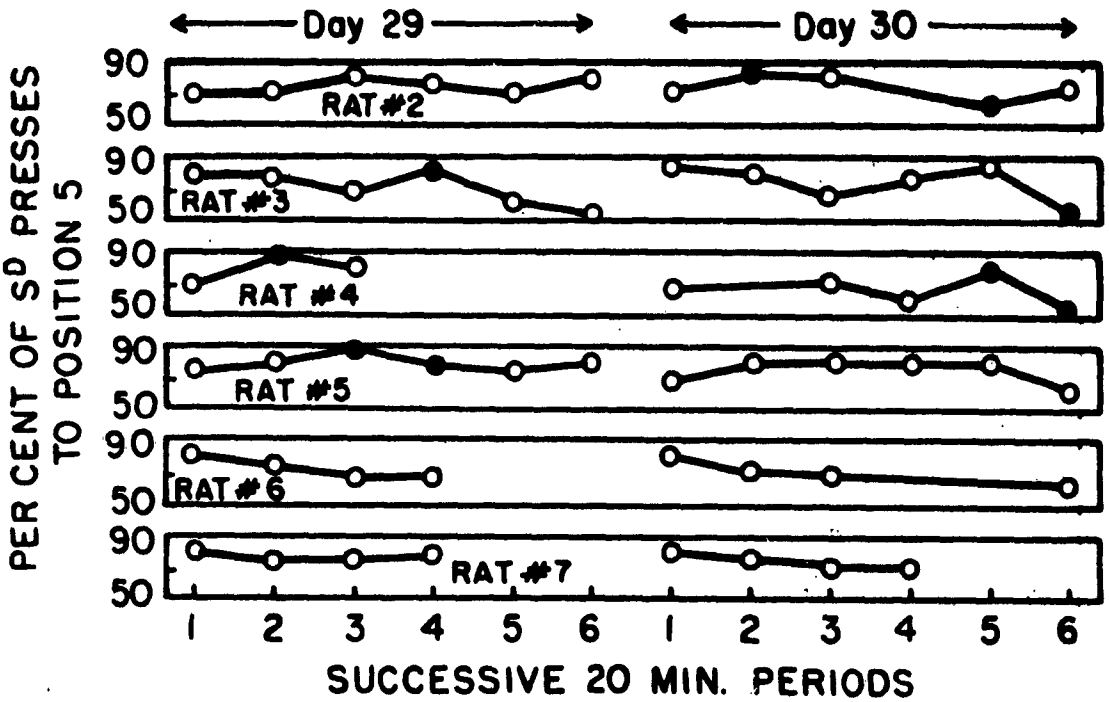

Figure 13. Variability in the percentage of S^D presses to Position 5 during the last two days of Phase IV. A filled-in point means that the percentage represented differed significantly (.05 level, "two-tail test"; Wallis & Roberts, 1956, p 429) from the preceding percentage. A point was not included if less than 20 S^D presses were made in the 20-minute period.

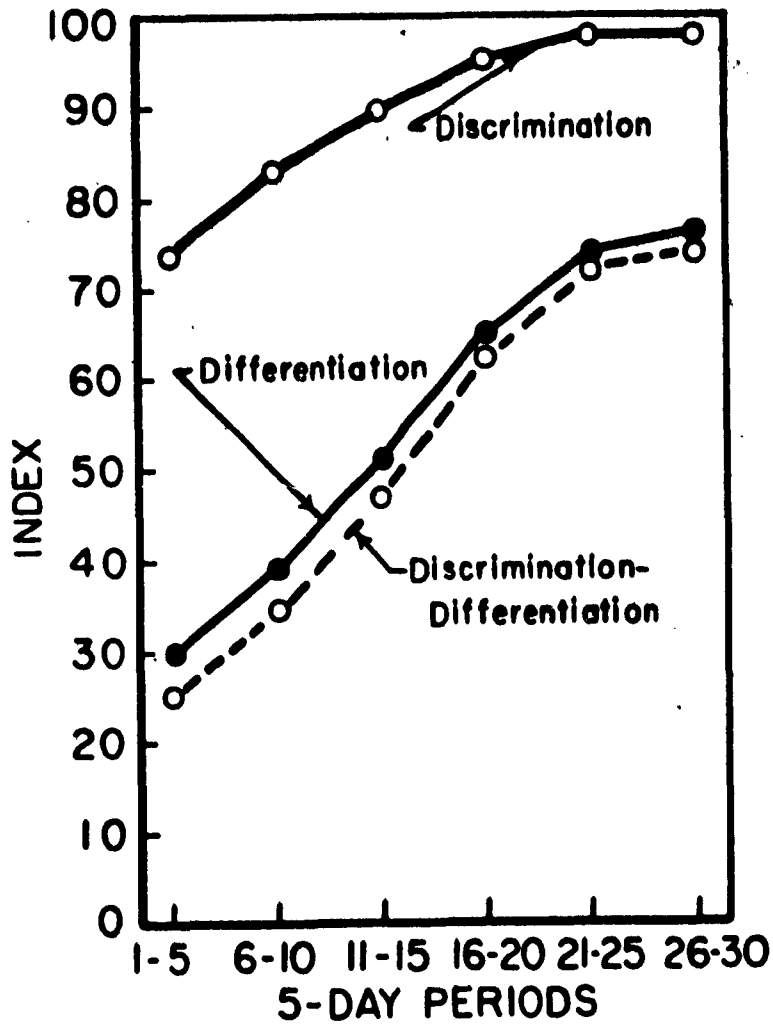

Figure 14. Three indices of the discrimination - differentiation in Phase IV. The indices are defined in the Fig. 7 caption. Period of Day 11-15 represents data of only 3 days.

REFERENCES

1. Arnold, W.J. An exploratory investigation of primary response generalization. J. comp. Psychol., 38, 87-102, 1945.

2. Elliott, M.H. The effect of hunger on variability of performance. Amer. J. Psychol., 46, 107-112, 1934.

3. Herrick, R.M. Lever displacement during continuous reinforcement and during a discrimination. J. comp. physiol. Psychol. (in press)

4. Notterman, J.M. & Mintz, D.E. Exteroceptive cueing of response force. Science, 135, 1070-1071, 1962.

5. Siegel, S. Nonparametric statistics for the behavioral sciences, New York: McGraw-Hill, 1956.

6. Skinner, B.F. The behavior of organisms. New York: Appleton-Century, 1938.

7. Wallis, W.A. & Roberts, H.V. Statistics: A new approach. Glencoe, Ill.: Free Press, 1956.

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The maximum displacement of the T-bar handle of a rat response lever was recorded under two schedules: (a) programmed variable-duration S^D and S^Δ periods with reinforcement only for S^D presses between 23.54° and 28.64° (Position 5) and (b) the same requirements for a reinforcement as in (a) but with S^Δ initiated only by a "wrong" press in S^D, and prolonged by any press in S^Δ. With this lever, work is linearly proportional to displacement. Under the first schedule (a) S^D distributions differed significantly from their companion S^Δ distributions, although the lever position showing the greatest percentage of presses in S^D often corresponded with the one showing the greatest percentage in S^Δ and (b) both mean lever displacement and variability were consistently greater in S^Δ than in S^D. Under the second schedule (a) S^D distributions differed significantly from their companion S^Δ distributions, but the S^D - S^Δ distributions were positively correlated and (b) mean lever displacement was about the same in S^D and S^Δ, but variability was consistently greater in S^Δ. Under both schedules (a) the previously-established discrimination was disrupted initially, but eventually reached very high levels, (b) the final shape of the S^D distribution was asymmetrical with respect to Position 5; more presses occurred below than above Position 5, (c) the greater the distance from Position 5, the lower the final percentage achieved, (d) while the mean response rate in S^D decreased under lowered motivation, the distance the lever was pressed remained unchanged.

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